Reaction of rice cultivars to *Meloidogyne graminicola* as a function of irrigation management

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**ABSTRACT**

The objective of this study was to evaluate the reproduction of *Meloidogyne graminicola* in 22 cultivars of rice used in the southern region of Brazil according to the irrigation management. The design was completely randomized in a factorial scheme, being the factor A: rice cultivars and factor B: irrigation management (dry and flooded). The rice cultivars were kept individually in pot with sterilized substrate and inoculated with 5,000 eggs and juveniles (second stage - J2) of the nematode. Plants to rice cultivate BRS IRGA 410 was inoculated with *M. graminicola* and were used as controls. At 60 days after inoculation, the root system of each plant was evaluated number of galls (NG), number of nematodes per gram root (NNGR) and the reproduction factor (RF). The results demonstrate that *M. graminicola* can parasitize and develop in different rice cultivars that are commonly used in commercial crops in the Southern region of Brazil, and all cultivars evaluated were classified as susceptible to this nematode (FR> 1.00). The cultivation system under flood conditions showed significantly lower values for the NG, NNGR and RF.

**Highlighted Conclusions**

1. The cultivars BRS Firmeza, IRGA 421, IRGA 423, IRGA 424, IRGA 436, IRGA 428 CL, IRGA 429, Inov CL, Avaxi CL, BRS Catiana and SCS121 CL showed the lowest RF in the flooded crop.

2. The use of cultivars with lower nematode RF in early flood cropping systems is a strategy indicated to reduce the population and the potential for damage caused by *M. graminicola* in areas with rice crop.

**INTRODUCTION**

Rice (*Oryza sativa* L.) is the most cultivated and consumed crop worldwide, being the basic food for about 3.5 billion people, consisting in a strategic crop both economically and socially (Fidelis et al. 2012, Muthayya et al. 2014). In the world, estimatives indicate that approximately 480 million tons of benefitted rice are produced annually (Muthayya et al. 2014). Brazil cultivates an area of approximately 1.97 million hectares of irrigated rice, with production of 12.03 million tons of grains, and annual domestic consumption of 12 million tons (CONAB 2018). The Rio Grande do Sul state, where the irrigated cultivation system predominates, is the main Brazilian producer, accounting for 68.9% of the national rice production (Brasil 2018).

The rice crop may have negative interference of different biotic and abiotic stresses throughout its development cycle. Among the biological factors that affect the development and productivity of rice is the negative effect caused by competition with weeds, diseases and pests. Therefore, one of the main pests that occurs in the crop is the root-knot nematode (*Meloidogyne graminicola* Golden and Birchfield) that can cause a great decrease in the productive potential of the rice (Golden and Birchfield 1965). The productivity losses caused by this plant-parasitic nematode can vary from 11 to 90%, depending on the different sensitivity levels of the rice cultivars (Soriano and Reversat 2003, Padgham et al. 2004, De Waele and Elsen 2007, Kynsd et al. 2014).

The occurrence of *M. graminicola* species was initially reported by parasitizing *Echinochloa colonum* (L.) roots and later found in rice, both in the United States (Golden and Birchfield 1965, 1968). There are currently reports...
that this plant-parasitic nematode can parasitize more than 100 plant species, including grasses and dicotyledons (Naalden et al. 2018). In this way, it is widely distributed in almost all producing countries, parasitizing rice crops in flooded systems and dry systems (Dutta et al. 2012, Jain et al. 2012). In Brazil, M. graminicola has been detected since the 1990s, parasitizing rice plants and rice grass (Echinochloa sp.) in fields from Rio Grande do Sul State (Sperandio and Monteiro 1991, Gomes et al. 1997). It has recently been reported that M. graminicola is the predominant plant-parasitic nematode species in the main rice-growing areas of the country (Negretti et al. 2017).

The management of Meloidogyne spp. requires different tools, as use of resistant genotypes and the implementation of crop rotations with non-host species (Mattos et al. 2017). However, options to manage M. graminicola are still limited, because of the few resistant rice genotypes (Dutta et al. 2012, Phan et al. 2018).

Studies report lower yield losses of rice cultivation caused by M. graminicola, when the crop was submitted to early flooding and the water maintained until the end of its crop cycle, this can be a tool for the management of this plant-parasitic nematode (Soriano et al. 2000, De Waele and Elsen 2007). Thus, the selection of susceptible cultivars to M. graminicola and the effect of the water depth on the development of this nematode can contribute to obtain resistant genotypes to be used in management programs and to indicate management strategies of this important parasite of rice cultivation. In this context, the objective of this work was to evaluate the reproduction of M. graminicola in rice cultivars used in the southern region of Brazil due to the absence or presence of irrigation by submersion.

MATERIAL AND METHODS

The experiment was conducted from agricultural crop year 2018 to assess the reaction of 22 different rice cultivars (Avaxi CL, BRS Atalanta, BRS Catiana, BRS Firmeza, BRS Pampa, BRS Querência, BRS Sinuelo CL, Guri Inta CL, Inov CL, BR IRGA 410, IRGA 417, IRGA 421, IRGA 423, IRGA 424, IRGA 426, IRGA 428 CL, IRGA 429, Puitá Inta CL, SCS117 CL, SCS121 CL, and Titan CL) to M. graminicola under greenhouse conditions with temperatures ranging from 22.5 to 27°C. The management of nematodes, showed a significant interaction on the parasitism capacity of the root-knot nematode, M. graminicola (Table 1). For all cultivars evaluated, the flooded

RESULT AND DISCUSSION

The different rice cultivars, as well as the different irrigation management, showed a significant interaction on the parasitism capacity of the root-knot nematode, M. graminicola (Table 1). For all cultivars evaluated, the flooded
system allowed significantly higher values for the number of galls (NG), nematode per gram of roots (NNGR) and reproduction factor (RF) of the root-knot nematode (Table 1).

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>NG Dry</th>
<th>NNGR</th>
<th>RF Floated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avaxi CL</td>
<td>346 c²</td>
<td>250 c</td>
<td>1676 c²</td>
</tr>
<tr>
<td>BR IRGA 410 T</td>
<td>950 a</td>
<td>576 a</td>
<td>5690 a²</td>
</tr>
<tr>
<td>BRS Atalanta</td>
<td>496 c</td>
<td>331 b</td>
<td>2256 c²</td>
</tr>
<tr>
<td>BRS Catiana</td>
<td>402 c</td>
<td>280 c</td>
<td>1867 c²</td>
</tr>
<tr>
<td>BRS Firmeza</td>
<td>379 c</td>
<td>214 d</td>
<td>1336 d²</td>
</tr>
<tr>
<td>BRS Pampa</td>
<td>608 b</td>
<td>392 b</td>
<td>2759 c²</td>
</tr>
<tr>
<td>BRS Pampeira</td>
<td>700 b</td>
<td>441 b</td>
<td>4265 b²</td>
</tr>
<tr>
<td>BRS Querência</td>
<td>658 b</td>
<td>419 b</td>
<td>3327 b²</td>
</tr>
<tr>
<td>BRS Sinuelo CL</td>
<td>696 b</td>
<td>439 b</td>
<td>3251 b²</td>
</tr>
<tr>
<td>Guri Inta CL</td>
<td>454 c</td>
<td>308 c</td>
<td>2250 c²</td>
</tr>
<tr>
<td>Inov CL</td>
<td>421 c</td>
<td>290 c</td>
<td>2085 c²</td>
</tr>
<tr>
<td>IRGA 417</td>
<td>298 d</td>
<td>191 d</td>
<td>1403 d²</td>
</tr>
<tr>
<td>IRGA 421</td>
<td>290 d</td>
<td>171 d</td>
<td>964 e²</td>
</tr>
<tr>
<td>IRGA 423</td>
<td>258 d</td>
<td>126 d</td>
<td>1282 d²</td>
</tr>
<tr>
<td>IRGA 424</td>
<td>254 d</td>
<td>150 d</td>
<td>1261 d²</td>
</tr>
<tr>
<td>IRGA 426</td>
<td>396 c</td>
<td>277 c</td>
<td>1948 c²</td>
</tr>
<tr>
<td>IRGA 428 CL</td>
<td>267 d</td>
<td>145 d</td>
<td>1375 d²</td>
</tr>
<tr>
<td>IRGA 429</td>
<td>263 d</td>
<td>153 d</td>
<td>1293 d²</td>
</tr>
<tr>
<td>PUITÁ INTA CL</td>
<td>479 c</td>
<td>322 b</td>
<td>2260 c²</td>
</tr>
<tr>
<td>SCS117 CL</td>
<td>575 b</td>
<td>374 b</td>
<td>2924 b²</td>
</tr>
<tr>
<td>SCS121 CL</td>
<td>413 c</td>
<td>286 C</td>
<td>2131 c²</td>
</tr>
<tr>
<td>Titan CL</td>
<td>542 b</td>
<td>356 b</td>
<td>2757 c²</td>
</tr>
</tbody>
</table>

| Average         | 450    | 300   | 2289       |

| CV (%)          | 16.75  | 18.95 | 21.5       |

¹ Number of nematodes per gram of root: ratio between total nematodes and total root mass
² RF = Final population/Initial population
³ Means followed by different lowercase letters in the column differ from one another by the Scott-Knot test (p<0.05), comparing the cultivars. * e.s. significant and not significant, respectively, by the t test (p<0.05), comparing irrigation managements.
T: susceptible control.

The control cultivar BR IRGA 410 showed the lowest values for the NG, NNGR and RF variables in both water management systems, when compared to the other cultivars (Table 1). In the dry system, this cultivar average values of 950, 5690 and 57.2 for the variables NG, NNGR and RF, respectively. However, the same cultivar in the flooded system showed significantly lower mean values with a reduction of 39.4; 48.3 and 55.2% for NG, NNGR and RF, respectively. Therefore, flooding significantly reduces the parasitism and multiplication capacity of *Meloidogyne graminicola*.

The cultivars IRGA 417, IRGA 421, IRGA 423, IRGA 424, IRGA 428 CL and IRGA 429 showed the lowest values for the number of galls per roots for both irrigation systems (Table 1). While the cultivar BRS Firmeza showed intermediate results for NG in the dry system, but for the flooded condition lower values and, in conjunction with the cultivars mentioned above, obtained the lowest performance for NG. For the variable nematode number per root number of nematodes per gram of roots, the cultivar IRGA 421 obtained the lowest value in the rainfed system, with 964 individuals (NNGR). The cultivars IRGA 423, IRGA 429, IRGA 421, IRGA 424, BRS Firmeza, IRGA 428 CL and IRGA 417 showed the lowest values of NNGR, with 532, 640, 702, 846, 871, 909 and 963 individuals, respectively.

All the 22 rice cultivars evaluated showed a reproduction factor higher than 1.00, irrespective of the irrigation management, and were considered susceptible to *M. graminicola* according to the classification proposed by Oostenbrink (1966). However, it was observed that all rice cultivars submitted to the flood-irrigated system lower values for the reproductive factor when compared to the dry system (Table 1). It was observed that the cultivars BRS Firmeza, IRGA 417, IRGA 421, IRGA 423, IRGA 424, IRGA 436, IRGA 428 CL and IRGA 429 presented the
smallest reproduction factors for both irrigation systems, whereas in the flooded crop, the cultivars Inov CL, Avaxi CL, BRS Catiana and SCS121 CL also resulted in the lowest values of RF along with the cultivars mentioned above. The damages caused by *M. graminicola* in the rice crop is related to the survival capacity and complete development of the plants, occurring for crops grown in dry or flooded systems. The results of the present study show that this plant-parasitic nematode is adapted to different environments, can survive under flood conditions, and thus may cause damage in different rice agroecosystem. The survival and damage caused by *M. graminicola* in distinct environments is also reported by other studies which also connect their infestation from egg deposition on the roots performed by adult individuals or from the migration of juvenile from the soil generating the formation of new galls (Dutta et al. 2012, Kyndt et al. 2014, Mantelin et al. 2017).

The classical infestation of *M. graminicola* leads to the formation of root galls (popularly known as "umbrella cables") at the tip of young roots (Gomes et al. 1997). These galls in the rice crop cause the alteration of the vascular system, causing disruption of water and nutrient transportation, stuntling, chlorosis, loss of vigor, reduction of the number of tillers, poor growth and reproduction of the plants, resulting in significant losses (Bernard et al. 2017, Mantelin et al. 2017). The average losses in rice cultivation due to this nematode species vary between 17% and 32% and can reach up to 90% in yield reduction in cases of high infestations (Padgham et al. 2004, Kyndt et al. 2014).

The reduction of infestation and reproduction of *M. graminicola* was evidenced in the present study for the condition of soil flooding, indicating a greater tolerance by the crop and reduction of plant-parasitic nematode adaptability to a condition of lower oxygen. The present study corroborates with the results reported in studies where the sowing of the cultivars Thhtatys and Yatanarto in an environment with presence of water lamina or submitted to early irrigation, reduced the infestation and the damages caused by *M. graminicola* in comparison with the sowing in dry soil or with late irrigation (Win et al. 2016). In this sense, the onset of flooding immediately after sowing or sowing in pre-germinated systems may limit the infestation capacity of the roots by the nematode (Soriano et al. 2000, Gilces et al. 2016). Thus, reducing the presence of the nematode can reduce yield losses with the use of precocious flooding or before sowing of the crop, becoming a tool of management of this phytoparasite.

The results obtained demonstrate that the *M. graminicola* can parasitize, develop and reproduce in different rice cultivars that are commonly used in commercial crops in the southern Brazil. They also show that this phytoparasite can develop in rice plants cultivated under dry and flooded system, however, presenting a lower number of galls, nematode per gram of root and reproduction factor in the flooding. Thus, it is necessary to adopt integrated practices for the efficient management of this important nematode species of rice crop, with the adoption of less sensitive cultivars, flooding of the area and rotation of crops with resistant species. In this way, the population of this plant-parasitic nematodes can be reduced in cultivated areas and minimized the losses caused by *M. graminicola* in rice crop.

References

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